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FAILURE ANALYSIS INVESTIGATION OF NIKE-HERCULES HOISTING CHAIN.(U)
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TECHNICAL REPORT E-79-6

FAILURE ANALYSIS INVESTIGATION OF NIKE-HERCULES HOISTING CHAIN

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U.S. ARMY
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The failure of the hoisting chain used on the NIKE-HERCULES System was investigated to determine the cause of failure. The metallurgical and mechanical exploitation of the chain revealed an overloading condition as the cause of failure. The ultimate tensile load of the chain exceeded the working load requirement by a factor of 6.

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CONTENTS

I. INTRODUCTION AND BACKGROUND

The Maintenance Engineering Directorate (DRSMI-NSS) requested DRDMI-EAM to investigate the cause of failure of the chain used to lift the NIKE-HERCULES missile.

Reports received from NEAS (Dave Kutz) were that the chain failed during lifting and handling of the missile, and that upon failure the missile dropped approximately 6 in. (15.24 cm) before coming to rest. Failure in the chain link was approximately 2-ft (0.61-m) above the chain hook.

The technical manual requires that this chain be load tested to 10,050 lb (44.7 KN). The chain working load is approximately 6700 lb (29.8 KN).

Approximately 12 ft (3.7 m) of the chain was received from DRSMI-NSS with the failed link attached to the main chain body as shown in Figure 1.

A new chain linkage, approximately 1-ft (30.5-cm) long, that represents the type of chain that will replace the existing chain was also received.

All further references to the two chains will be noted as "old chain" (failed chain) and "new chain" (replacement chain).

II. DISCUSSION

The failed link of chain was cut from its present link and macrographs of the fracture surface were taken. Figure 2 shows the mirror image fracture surfaces with the origin of failure indicated.

Metallographic examination of the weld area of the old and new chains was conducted. Figures 3 and 4 show the weld areas of the old and new chains, respectively. The old chain weld area shows evidence of surface cracks in the weld area while the new chain weld area is free from any cracks or irregularities. Further metallurgical examination of the weld area in the old chain showed evidence of cracking and voids in the heat affected zone. (See Areas A and B of Figure 3.) Figures 5 and 6 show these areas at a high magnification of 400X.

Figure 4 is a macrograph of the new chain weld area. Further metallurgical examination of this weld at 400X did not reveal any voids and/or cracks.

Two sections of the old chain and the one section of the new chain were loaded in tension to failure. Figure 7 shows a typical test setup. One other section of chain with the midpoint chain link cut through its weld area was loaded to failure (Figure 8). Rockwell hardness valves were run on the old and new chain indicating values of RC 35 and 31, respectively. All of the previously mentioned mechanical test results are presented in Table 1.

III. RESULTS

Metallurgical investigation of the old and new chains revealed cracks and voids which could act as points of high stress intensity in the old chain (Figures 3, 5, and 6) and complete absence of cracks and voids in the new chain.

These cracks and voids are restricted to the weld area and are a result of the welding procedures used in the manufacturing process.

Chemical analysis of the old and new chains indicated that the alloy composition was SAE 8625 alloy steel.

The ultimate loads required to fail the old and new chains exceeded the chain working load by a factor of 6 for the old chain and by a factor of 5.8 for the new chain.

It should be noted that the fracture area in the old chain was through the weld area, while the new chain fractured in the base metal (Figures 9 and 10). This mode of failure is primarily because of the smaller effective weld area in the old chain. [See Figure 3, Area D dimension, and Figure 4, Area A dimension, for respective diameters of 0.482 in.(1.22 cm) and 0.550 in.(1.4 cm).]

The tensile test conducted on the old chain with the weld cut through (Figure 8) exhibited an upper load limit of 6450 lb (28.7 KN). This link had an initial opening of 0.0700 in.(1.78 mm) at zero load. Deflection measurements were taken at five different load levels by stopping the test machine and using a feeler gage to measure the displacement in the cut link.

The cut opening increased in size as loading increased on the chain link. When the load level reached 6450 lb (29.6 KN) there was no further load increase (Figure 11), and the cut link extended and became disengaged from its parent link (Figure 12).

IV. CONCLUSIONS

Chemical analysis of the base metal and weld area of the old and new chains indicated the chain material to be grade SAE alloy steel 8625. The grade SAE 8625 alloy steel is frequently used in the manufacture of chains. Table 2 presents the chemical analysis data.

The hardness surveys across the diameter of the link were taken every 0.063 in.(0.159 cm). The hardness survey and metallurgical examination of the cross section indicate that the chain had been properly heat treated.

The results of the tensile tests clearly indicate that the ultimate strength level of the old and new chains exceeds the load requirements for the NIKE-HERCULES hoisting chain by a factor of approximately 6 (6 for the old chain, 5.8 for the new chain).

The metallurgical examination of the weld area, Figures 5 and 6, revealed cracks and voids in the old chain are representative of a typical welded chain link. The maximum depth of these internal cracks is 0.0022 in.(0.057 mm) as shown by Area A of Figure 6. (This scale factor is 0.4 in. = 0.0001 in.) The macrograph of the old chain weld area (Figure 3, Area C) shows surface cracks, the maximum depth of which is 0.0166 in.(0.4 mm). (This scale factor is 0.1 in. = 0.0166 in.)

Previous studies conducted in the area of notch sensitivity of chains[1] of this alloy type indicate that this chain is virtually unaffected by the presence of a 0.1-in.(2.54-mm) deep flaw. As a result of this study one can readily see that the 0.0022-in.(0.057-mm) and 0.0166-in.(0.4-mm) crack depths, Figures 6 (Area A) and 3 (Area C), respectively, are of no serious consequence to sudden fracture of chains investigated in this study.

Because of the previously mentioned findings it is the opinion of the Materials Engineering and Development Laboratory that the chain failure was caused by an overloading condition and that the failure initiation site is as shown in Figure 2.

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[1] R. F. McCartney and J. V. Pellegrino, "Strength Toughness and Flaw Tolerance of 25.4-mm (1-in.) Alloy Steel Lifting Chain," ASTM STP 645, American Society for Testing Materials, 1978, p. 312.

V. RECOMMENDATIONS

As a result of this study it is recommended that the existing (old) chains be approved for continued service. However, it is the opinion of Materials Engineering and Development Laboratory that when the old chain is retired that it be replaced with the new chain because of its superior weldment qualities.

TABLE 1. MECHANICAL PROPERTIES*

Chain	Ultimate Load kip (KN)	Area $in.^2$ (cm^2)	Ultimate Stress ksi (MB)	Hardness Rockwell-C
Old Chain No. 1	42.6(189.5)	0.183(1.18)	232.7(1603.9)	35
Old Chain No. 2	42.6(189.5)	0.183(1.18)	232.7(1603.9)	35
New Chain	39.0(173.5)	0.196(1.27)	198.9(1.371)	31
Old Chain (with Weld Cut)	6.45(28.7)	NA	NA	35

*All tensile tests were conducted at a crosshead speed of 0.25 in./min (0.64 cm/min).

TABLE 2. CHEMICAL ANALYSIS*

OLD CHAIN

Q01CHAIN- -AVE 2.3

C	0.249	MN	0.940	P	0.047	S	0.014	SI	0.325	NI	0.52	CR	0.48
MO	0.188	CU	0.050	TI	0.003	V	0.006	W	0.055	NB	0.019	CO	0.023
TA	0.000	AL	0.125	ZR	0.016	SN	0.017	PB	0.000	AS	0.038	SB	0.000
SE	0.000	CA	0.000	CE	0.000	B	0.001	MG	0.006	TE	0.000	BK	0.027
CV	100.0												

NEW CHAIN

Q01CHAIN- .AVE 1.2.3

C	0.250	MN	0.798	P	0.057	S	0.027	SI	0.215	NI	0.41	CR	0.46
MO	0.075	CU	0.147	TI	0.004	V	0.005	W	0.053	NB	0.019	CO	0.029
TA	0.000	AL	0.041	ZR	0.015	SN	0.018	PB	0.000	AS	0.061	SB	0.000
SE	0.000	CA	0.000	CE	0.000	B	0.001	MG	0.006	TE	0.000	BK	0.026
CV	100.0												

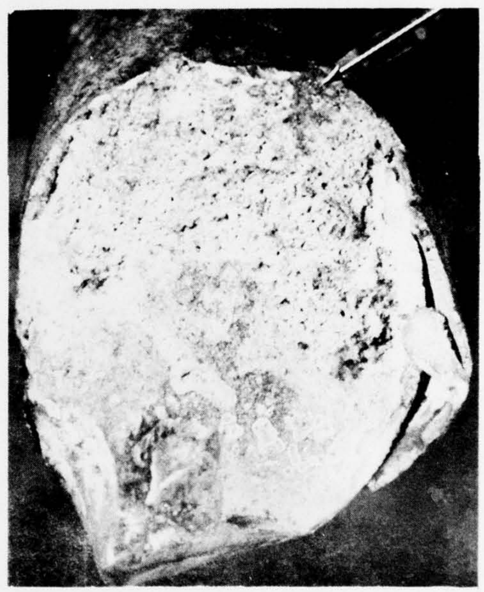
*Analysis generated on Baird-Atomic Spectrocomp System copyright Baird-Atomic 1973.

Figure 1. Isometric representation of NIKE-HERCULES hoisting chain as received.

(a)

(b)

(c)



(d)

NOTE: FIGURES (a) AND (b) ARE MIRROR IMAGES AND
FIGURES (c) AND (d) ARE MIRROR IMAGES.

Figure 2. Macrograph mirror image of fracture surface (fracture origin at arrow) (magnification 6X).

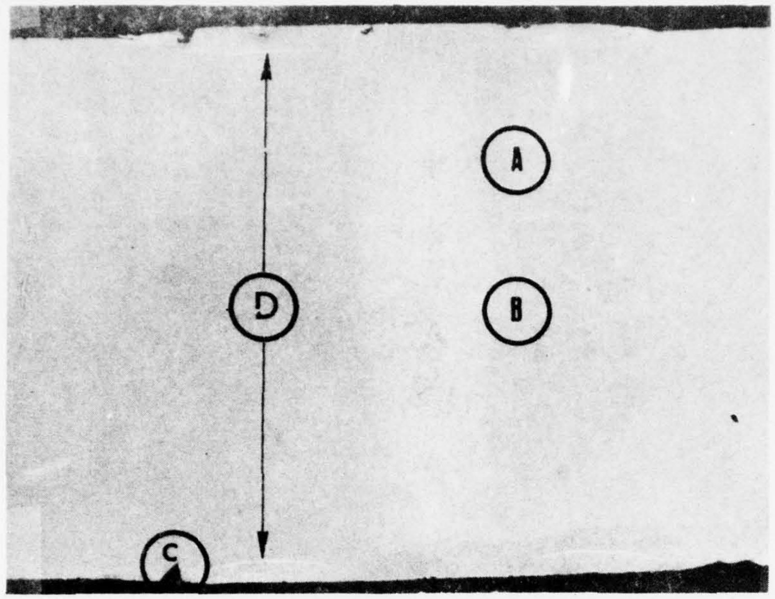


Figure 3. Typical weld area (old chain)(magnification 6X).

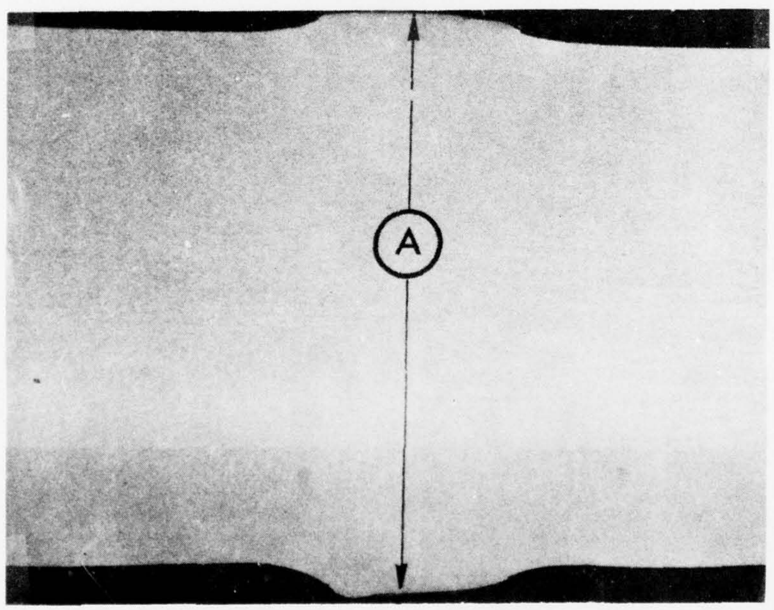


Figure 4. Typical weld area (new chain)(magnification 6X)

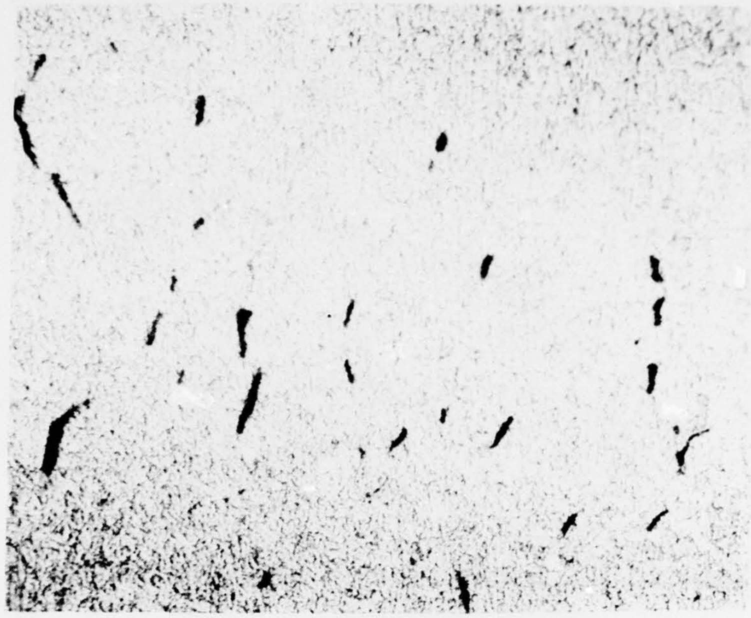


Figure 5. Micrograph of Area (A) of Figure 3 (magnification 400X).

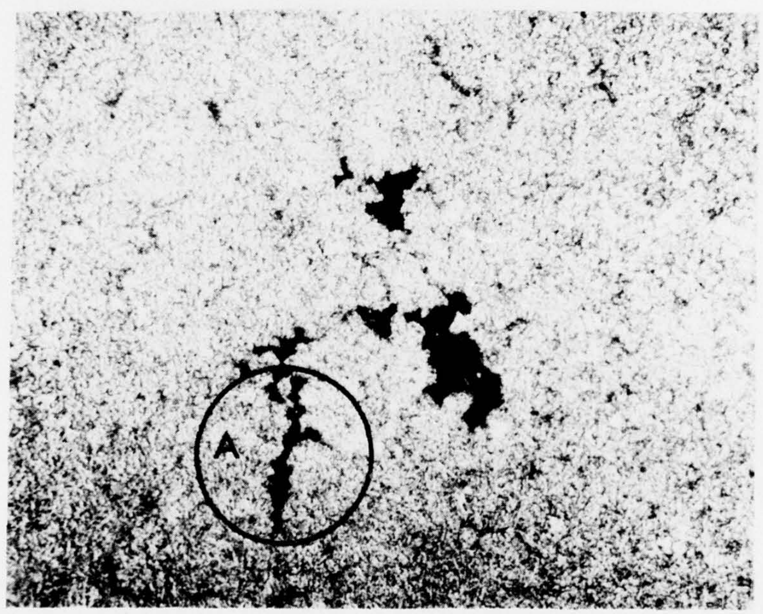


Figure 6. Micrograph of Area (B) of Figure 3.

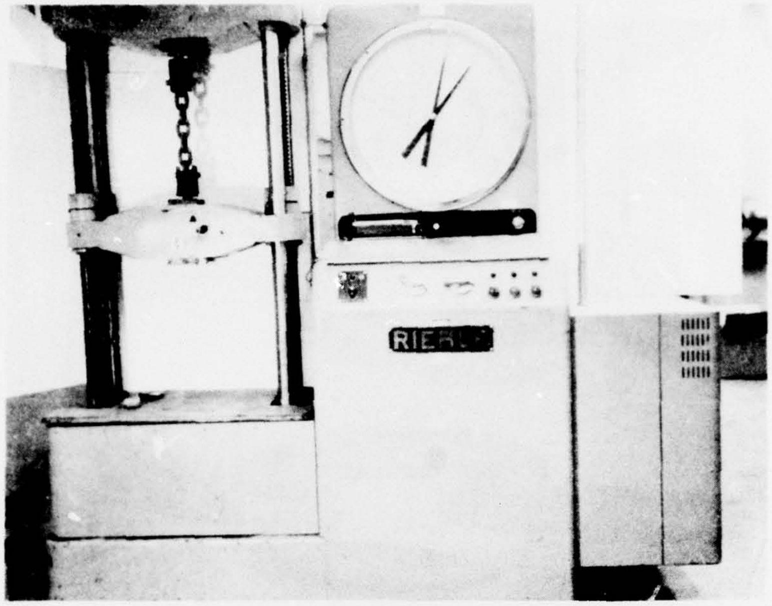


Figure 7. Typical tension to failure test setup.

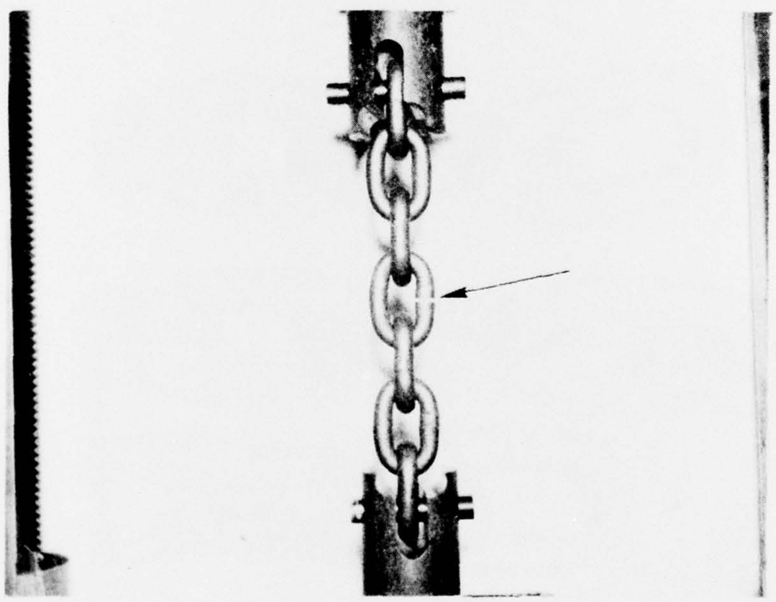


Figure 8. Tension test with weld area cut through (old chain).

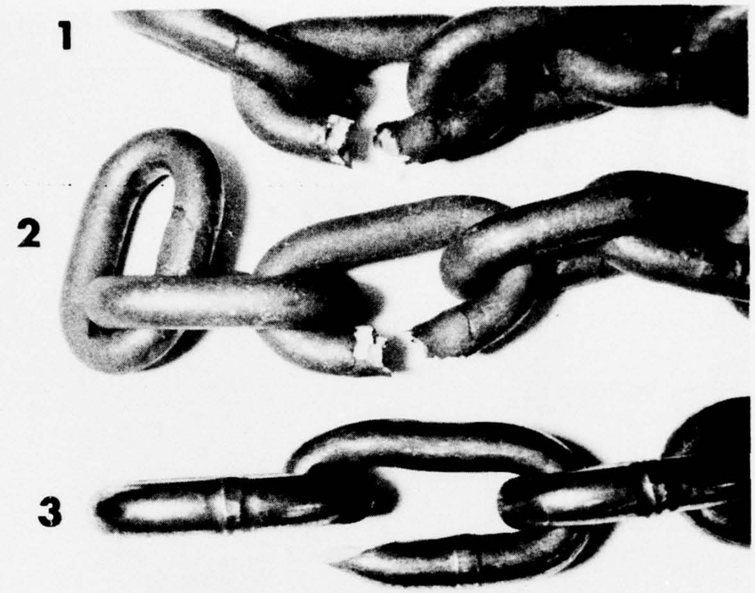


Figure 9. Chain tensile failures on old chain Nos. 1 and 2, and new chain No. 3.

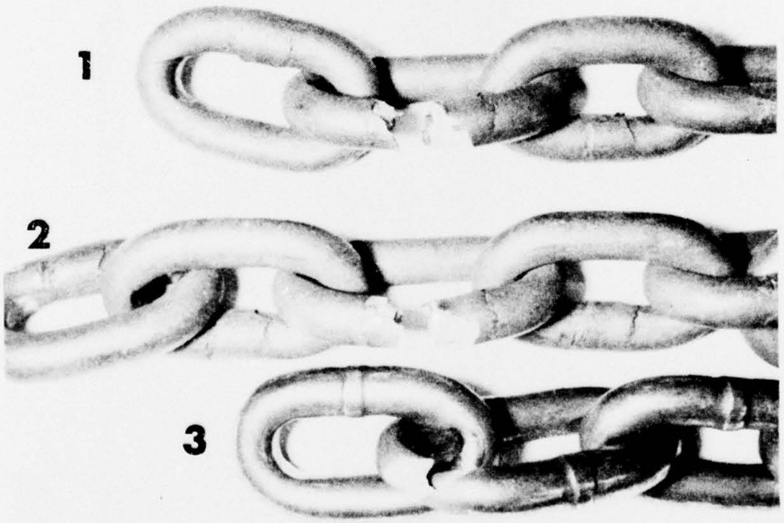


Figure 10. Chain tensile failures on old chain Nos. 1 and 2, and new chain No. 3.

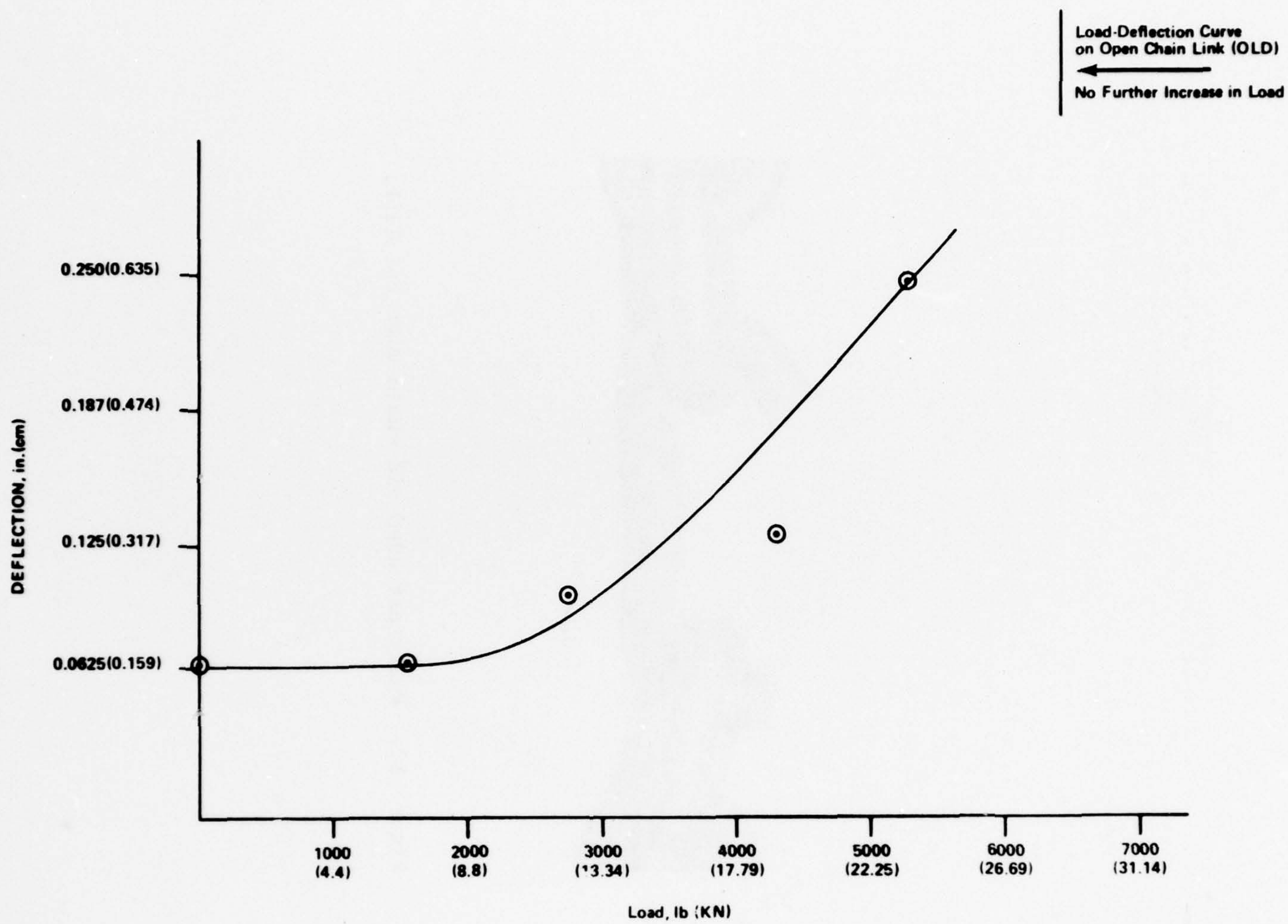


Figure 11. Load deflection curve of old chain with cut through weld.

Figure 12. Fully extended old chain with cut link.

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